

ROCKY MOUNTAIN NATIONAL PARK

TRAIL RIDGE ROAD

CO PRP 10 (3)

GEOTECHNICAL REPORT
Report # CO-PX-ROMO-01-01



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Trail Ridge Road, CO PRP 10 (3)

SECTION 1.0 INTRODUCTION

In June 2000, personnel in the Geotechnical Section of the Central Federal Land Highway Division (CFLHD) conducted a subsurface investigation of Trail Ridge Road that traverses a portion of Rocky Mountain National Park. On June 28th, 2001 additional site study was conducted to further examine the problem areas along the road and to verify the recommendations developed.

Rocky Mountain National Park is in north-central Colorado near the town of Estes Park, approximately 70 miles northwest of Denver, in the eastern Rocky Mountain Range. Trail Ridge Road (Colorado State Highway 34) is the main road through the Park, connecting the Estes Park Valley on the east and the Kawuneeche Valley on the west. The route is open from the end of May to mid October and is maintained by the Park Service. The vehicle weight and average daily traffic volume traveling on the paved roads of the park have increased significantly since these roads were constructed. The construction of Trail Ridge road was completed in late 1941 and was first paved in 1949. Park visitation has steadily increased from about 200,000 annual visits in 1930 to over 3 million annual visits today. This number is expected to increase to 4.9 million by 2020. Traffic volume was measured at Trail Ridge road west of Deer Ridge junction in August 1999. The average daily traffic volume on Trail Ridge road was as follows:

| Trail Ridge Road | Westbound ADT (Aug. 99) | Eastbound ADT (Aug. 99) |
|-----------------------------|-------------------------|-------------------------|
| | 24 hours | 24 hours |
| Weekend (Saturday & Sunday) | 2500 | 3916 |
| Weekday (Monday –Friday) | 1815 | 2715 |

Pavement sections and road geometry were not initially designed to accommodate the high stresses caused by recreational vehicles, buses and vehicles pulling trailers. The current posted speed for the route is 35 mph (55 kph). The existing roadway is a two-

lane thoroughfare with a paved surface width of 25 ft (7.5 m). There is little or no shoulder provided.

The highest road elevation on Trail Ridge Road is 12,183 ft (3,713 m), between the Lava Cliffs and Gore Range. Site maps, traffic data summaries, and traffic projections are attached in Appendix A and Appendix B, respectively. The purpose of this investigation is to determine the cause of failure and the level of rehabilitation required for three specific sites between Rock Cut and the Alpine Visitor Center. For the purpose of this report, the milepost designations (MP) begin at the intersection of the Alpine Visitor Center Parking lot and Trail Ridge Road.

The specific objectives of this investigation are to:

- 1) Drill auger holes in the roadway, determine the pavement and the base course thickness, classify the subgrade soil, and determine the causes of road failure
- 2) Document and evaluate existing subsurface conditions that may directly affect road failure and rehabilitation
- 3) Obtain sufficient data on pavement, subsurface conditions, moisture, traffic, and elevation to make recommendations for rehabilitation, structural sections, and drainage.

SECTION 2.0 GEOLOGY

Trail Ridge Road is located in the heart of Rocky Mountain National Park, which rises to impressive heights ranging from 7,800 to 14,260 ft (2,380 to 4,350 m) and includes Longs Peak, one of Colorado's highest point. These mountains are part of the northern Front Range that lies within the geologic province known as the Southern Rocky Mountains. These north-south trending mountains are characterized as broad-backed uplift, along whose crest erosion has laid bare wide areas of Precambrian rocks. These Precambrian rocks consist of granites, granitic gneisses, and biotitic schists that have been sculpted by several episodes of glaciations. These glacial features are present today as U-shaped valleys, hanging valleys, cirques, cirque lakes, and huge lateral moraines.

The soils consist mainly of glacial deposits and residual soils derived from weathering of the granitic basement rocks.

SECTION 3.0 PROCEDURES AND RESULTS

A subsurface soil survey was conducted at three separate areas along Trail Ridge road, between Forest Canyon Overlook and the Alpine Visitor Center, during June 2000. Site "A" was located about 5.8 miles (9.3 km) east of the Alpine Visitor Center (VC). Sites "B" and "C" are located about 1.5 and 0.4 miles (2.4 and 0.6 km) east of the Alpine Visitor Center, respectively. The survey consisted of drilling and sampling nine boreholes (boring numbers 00P-101 through 00P-109) along the roadway in alternating lanes approximately 6 ft (1.8 m) from the centerline of the road. Goodson & Associates, Inc. conducted all drilling, using a truck mounted CME-75 drill rig. FHWA-CFLHD personnel logged borings on site. All roadway and parking lot borings were 8 in. (200 mm) diameter and augered to a depth of approximately 15 ft (4.5 m). Standard Penetration tests were taken at 5 ft intervals (1.5 m). In certain cases, rock material such as large boulders was encountered and drilling was discontinued. Soil samples obtained from the borings were visually classified and logged. Selected samples were tested by the FHWA Central Federal Lands Materials Laboratory in Denver, Colorado. Representative samples of all soil types encountered were submitted for laboratory classification. The Unified Soil Classification ASTM D2487 and AASHTO M145 systems were used to classify the representative soil samples.

In general, all boreholes encountered well-graded, granular materials with good drainage consisting mostly of sandy soils with some silts and gravels (SW-SM and GW-GM). Only one boring, 00P-102, encountered clayey sand (SC) at a depth of 8.2 ft (2.5 m) below the road surface. Boring log tabulations describing borehole location, asphalt pavement thickness, and soil types encountered from each borehole are attached in Appendix C.

SECTION 4.0 DISCUSSION AND RECOMMENDATIONS

Pavement and drainage conditions at each of the evaluated sites along the roadway were evaluated. The following are discussions of the findings at each of the sites:

Site A: A large section, about 500 ft (150 m), of the road has subsided up to two feet (0.6 m) below the original grade. Although both lanes have settled, most of the subsidence has occurred in the outbound (west) lane. Several transverse cracks were mapped at about 20 ft (6 m) intervals. Shoulder wash out and drop off were also apparent within this area. Two non-functional cross drainage pipes existed within the subsided area. The drainage pipes are 8 and 24 in (200 and 600 mm) in diameter. Both pipes contained trapped sediments and the inlet to the 8 in (200 mm) pipe could not be found. At the south edge of this zone, a 5 ft (1.5 m) wide paved drainage ditch with 6 in (150 mm) curve existed with a drop inlet to the 24 in (600 mm) cross pipe. At the north edge of the subsided zone, another drainage ditch with gravel was installed. No ditches existed along the subsided zone. The natural slopes on the east and west side of this site are about 1V:6H, while the fill slope on the west side (outbound) of the road is 1V:3H. These gentle slopes combined with the location of the site in a drainage valley, cause most of the snow runoff to either penetrate the granular soil or run over the road surface, washing the silt fines particles out of the subgrade, causing subsidence.

Two borings were advanced along the roadway in this area to characterize the subsurface conditions and to determine the causes and depth of the subsided zones. Boring 00P-108 was advanced a total of 21 ft (6.45 m) below the road surface and was located in the outbound lane at approximately 6.5 ft (2 m) from the road centerline. The soil encountered was mostly well-graded, yellow brown silty sand with some rock fragments, classified as SM by the USCS. Standard Penetration Tests (SPT) measured at 5ft (1.5 m) intervals yielded a low N value of 7 for the soils to a depth of 16.5 ft (5 m) and an N value of 21 for the soils below a depth of 20 ft (6 m). The high SPT N-values measured at 10 ft (3 m) depth are most likely an indication of a boulder zone. This indicates that the soils are loose within the first 16.5 ft (5 m) depth. Boring 00P-109 was advanced at the same station as 00P-108 for a total of 16.5 (5 m) below the road surface

and was located in the inbound lane at 6.5 ft (2 m) from the road centerline. The soil encountered was similar to that in 00P-108 and was also classified as SM by the USCS. At this location, however, the measured SPT N-values were more than two times (N= 14, 15, and 23) those in the outbound lane. Although these N values are not very high, they indicate that most of the problems are caused by soil washing out below the outbound lane.

For embankment stabilization, it is recommended that, 500 ft (150 m) long section between the end of the paved drainage on the south end and the end of the cut slope on the north end is sub-excavated, rebuilt, and drainage improved. The subexcavation should extend across the entire road prism. Materials excavated should be to a minimum depth of 10 ft (3 m). Figure 1 of Appendix D shows a schematic of the subexcavation and subsurface rebuilding plan. Drainage should be improved by installing paved ditches with a drop inlet and standard 24 in (600 mm) culvert. The excavated area should slope 2% towards the center point of the zone and 2% towards the edge of the outbound (west) lane, allowing the water to flow into an outlet ditch.

Because of the topographic nature of the site and the potential for large amounts of water to infiltrate the soils or run across the road, it is also recommended that a qualified hydrologist perform a detailed hydraulic evaluation to quantify the volume of water penetrating the soil. It is possible that the current structures handling drainage along this section of the road may be undersized and unable to handle the large amounts of runoff during periods of snowmelt. All culverts and inlets should be inspected periodically and flushed, if necessary, to optimize their performance.

Site B: A 300 ft (90 m) section of the outbound lane has subsided. This portion of Trail Ridge road consists of cut and fill sections constructed on an exposed talus slope. The height of fill on the west side of the road is approximately 15 ft (4.5 m) has slopes slightly steeper than 1V:2H. The talus slope on the east side of the road has slopes up to 1V:1H. A paved ditch with a 6 in (150 mm) curb and 24 in (600 mm) drop inlet provides drainage for the north end of this site. The intersection of the paved ditch and the talus slope on the east side of the road provide drainage for the majority of this section. Transverse cracking of a low to moderate nature was found throughout this road section.

The north side of this site has no shoulder in the outbound (west) lane. The shoulder gradually increases to a width of 2 ft (0.6m) towards the south end of this section.

Four borings were advanced at site B to determine the subsurface conditions and possible failure mechanisms. Boring 00P-101 was advanced a total of 3.8 m below the road surface and was located 3 m from the road centerline in the inbound (east) lane. A dense silty sand was found to a depth of 2.5 m. Decomposed granite was encountered from 2.5 m to 3.8 m. An SPT measured from 5 ft (1.5 m) to 6.5 ft (1.9 m) resulted in refusal. Refusal is defined as a total of 50 blows to drive the sampler 0.5 ft (0.15 m), or a total of 100 blows to drive the sampler the entire 1.5 ft (0.45 m), or no downward movement of the sampler for a total of 10 blows. Boring 00P-102 was located in the inbound (east) lane 9.5 ft (2.9 m) from the road centerline. This boring encountered a silty sand with rock fragments to a depth of 8 ft (2.5 m). This soil was visually classified as SM in the USCS. From 8 ft (2.5 m) to 15.7 ft (4.8 m) a clayey sand and gravel, classified as SC in the USCS, was found. An SPT taken from 5 ft (1.5 m) to 6.5 ft (1.9 m) resulted in a low N value of 6, while an SPT taken from 9.8 ft (3.0 m) to 11.3 ft (3.45 m) yielded an N value of 37. An SPT taken at the bottom of the boring resulted in refusal. Boring 00P-103 was drilled 9.8 ft (3 m) from the road centerline in the inbound (east) lane to a depth of 14 ft (4.25 m). This boring encountered silty sand with gravel size rock fragments. An SPT conducted from 5 ft (1.5 m) to 6.5 ft (1.9 m) resulted in an N value of 13, while an SPT from 9.8 ft (3.0 m) to 11.3 ft (3.45 m) yielded an N value of 17. Boring 00P-104 was positioned 8.2 ft (2.5 m) from the road centerline in the outbound (west) lane and encountered silty sand with rock fragments to a depth of 15.7 ft (4.8 m). This soil was classified as GW-GM in the USCS. An SPT from 5 ft (1.5 m) to 6.4 ft (1.95 m) yielded an N value of 14. An N value of 63 resulted from an SPT taken from 9.8 ft (3.0 m) to 11.3 ft (3.45 m), while an SPT taken at the bottom of the boring resulted in refusal. Borings 00P-102, 00P-103, and 00P-104 measured the thickness of asphalt and base course to a depth of 1.6 ft (0.5 m). These areas along site B have been repeatedly patched and resurfaced, solving the subsidence problem only temporarily.

The problems within this section of Trail Ridge Road seem to be related to a loose fill material. It is recommended that a zone, starting at 50 ft (15 m) south of the "DIP" sign on the north side and extending to the south approximately 300 ft (91 m), be sub-

excavated and rebuilt. The sub-excavation should extend across the entire cross section of the road and to a minimum depth of 10 ft (3 m). The clay discovered in boring 00P-102 should be removed and backfilled with clean, suitable granular material. It is also recommended that the shoulder fill slope be flattened to 1V:2H on the west side of this section. The condition of the drop inlet and culvert on the north end of this section should be determined and replaced if necessary. Figure 2 of Appendix D shows the recommended sub-excavation and subsurface rebuilding plan.

Site B-1: An additional 300 ft (90 m) directly to the south of site B was found to have several dips in the outbound (west) lane. Boring 00P-101 was located within this section in the inbound lane. A silty sand with rock fragments was encountered to a depth of 8.2 ft (2.5 m). From 8.2 ft (2.5 m) to 12.5 ft (3.8 m) the material consisted of decomposed granite. Two standard penetration tests were conducted within this boring and both resulted in refusal. While the inbound lane consists of dense material, the outbound fill material visually appears to be loose, causing the subsidence problems.

While site B takes precedence over site B-1, it is recommended that the outbound lane be sub-excavated and rebuilt, if funds warrant. Figure 3 of Appendix D details the recommended sub-excavation and subsurface rebuilding plan.

Site C: Site C extends from the Gore Range Lookout to the gate just south of the Alpine Visitors Center, approximately 1 mile (1.6 km). Various minor dips, to a depth of 0.5 ft (0.15 m), exist along the outbound (west) lane. This portion of Trail Ridge road consists of cut and fill slopes. The natural material found within site C is a decomposed granite. Along the east side of the road, a paved ditch with widths up to 6 ft (1.8), and a 6 in (150 mm) curb provide drainage for much of this section. A 3 ft (0.9m) high, approximately 300 ft (90 m) long, wall on the east side of the road was inspected and found to be in good condition. A 300 ft (90 m) section of paved ditch, approximately 200 ft (60 m) south of the end of the wall controls drainage along the outbound (west) lane. Several drop inlets and culverts are in place throughout the east ditch.

Three boring were advanced at various locations throughout site C to determine the subsurface condition of the road. Boring 00P-105 was drilled in the inbound lane and

encountered silty sand with rock fragments to a depth of 13.1 ft (4.0 m). The soil was classified as SW-SM by the USCS. An SPT taken from 5 ft (1.5 m) to 6.5 ft (1.9 m) yielded an N value of 77, while refusal resulted from an SPT taken from 9.8 ft (3.0 m) to 11.3 ft (3.45 m). Boring 00P-106 was located in the inbound lane 13.1 ft (4 m) from the road centerline. This boring found silty sand with rock fragments, classified as SM by the USCS, to a depth of 14.8 ft (4.5 m). An SPT conducted from 5 ft (1.5 m) to 6.5 ft (1.9 m) resulted in an N value of 7, while an SPT from 9.8 ft (3.0 m) to 11.3 ft (3.45 m) yielded an N value of 90. Boring 00P-107, located 12.5 ft (3.8 m) from the road centerline in the inbound lane, found silty sand with rock fragments to a depth of 6.6 ft (2.0 m). An SPT conducted from 5 ft (1.5 m) to 6.4 ft (1.95 m) resulted in an N value of 19.

The subsidence problems within this section appear to be related to both snowmelt infiltration and a loose fill material. Drainage along the road seems to be adequate and in working order. It is recommended that the outbound (west) lane be sub-excavated and rebuilt throughout the section. This sub-excavation should extend from the road centerline to the outbound shoulder and to a depth of suitable material. Figure 3 of Appendix D shows the recommended sub-excavation and subsurface rebuilding plan.

Site D: Site D is a small section of Trail Ridge road that was investigated during the site visit in June 2001. Site D is approximately 195 ft (60 m) north of a stonewall found just north of the Lava Cliffs Turnout. Site D is 100 ft (30 m) long and consists of a 6 in (150 mm) dip found adjacent to a “20 MPH” curve sign along the outbound lane. A paved ditch with a 6 in (150 mm) curb is used to control drainage on the east side of the road. Low to moderate transverse cracks were observed with a spacing of approximately 10 ft (3 m). Site D consists of cut and fill slopes, with the toe of the fill slope 30 ft (10 m) below the road surface.

No borings were done at this site as it was recently added to the report.

The cause of subsidence at this site seems to be closely related to those found at site A. It is recommended that this 30 m (100 ft) zone be sub-excavated and reconstructed. As the problems seem to be occurring in the outbound lane only, the sub-excavation should be limited to the area between the road centerline and the outbound shoulder. It is

thought that the subsurface material found at Site D will be similar to the material found at the other sites. Therefore, sub-excavation should proceed to a depth of 10 ft of until suitable material is found. Figure 3 of Appendix D shows the recommended sub-excavation and subsurface rebuilding plan.

SECTION 5.0 CONSTRUCTION SPECIFICATIONS

The following specifications apply to the sites listed above, unless otherwise noted:

- 1) Both the sub-excavation and the backfill shall be constructed according to section 204 of FP-96.
- 2) Type II-A geo-textile separation fabric shall be installed in the sub-grade according to section 204 of FP-96.
- 3) Riprap shall be installed according to section 251 of FP-96.

APPENDIX A

TRAIL RIDGE ROAD

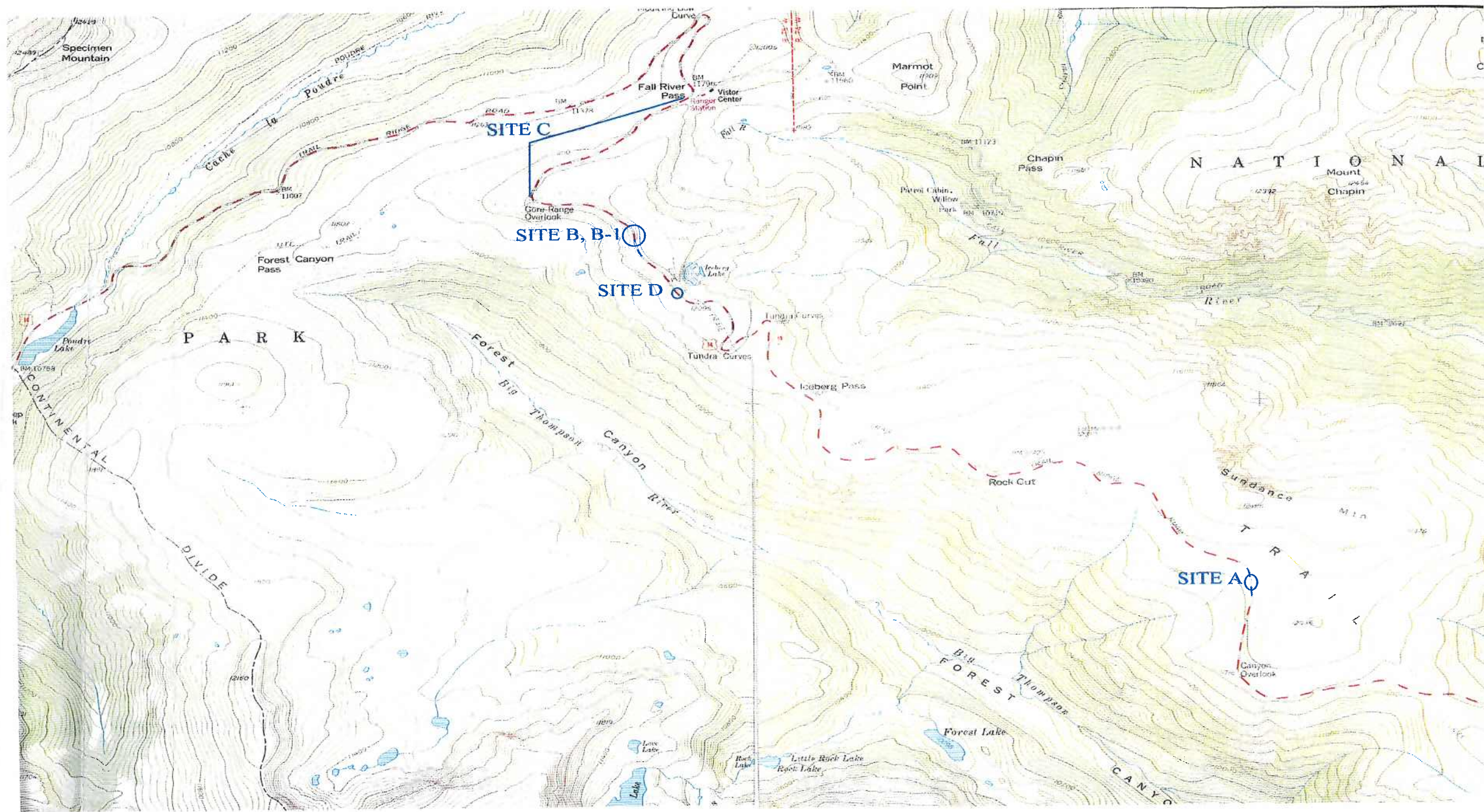
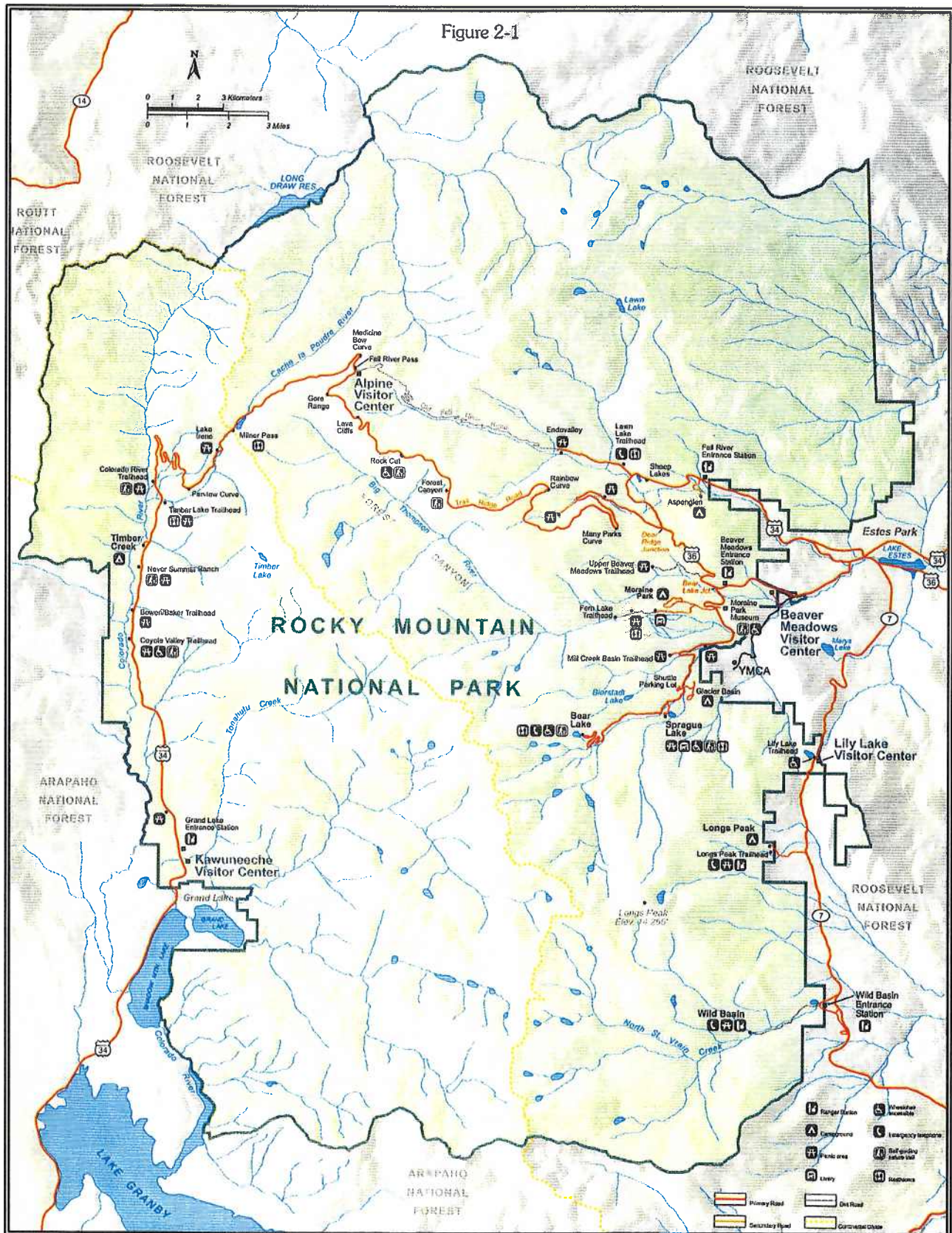
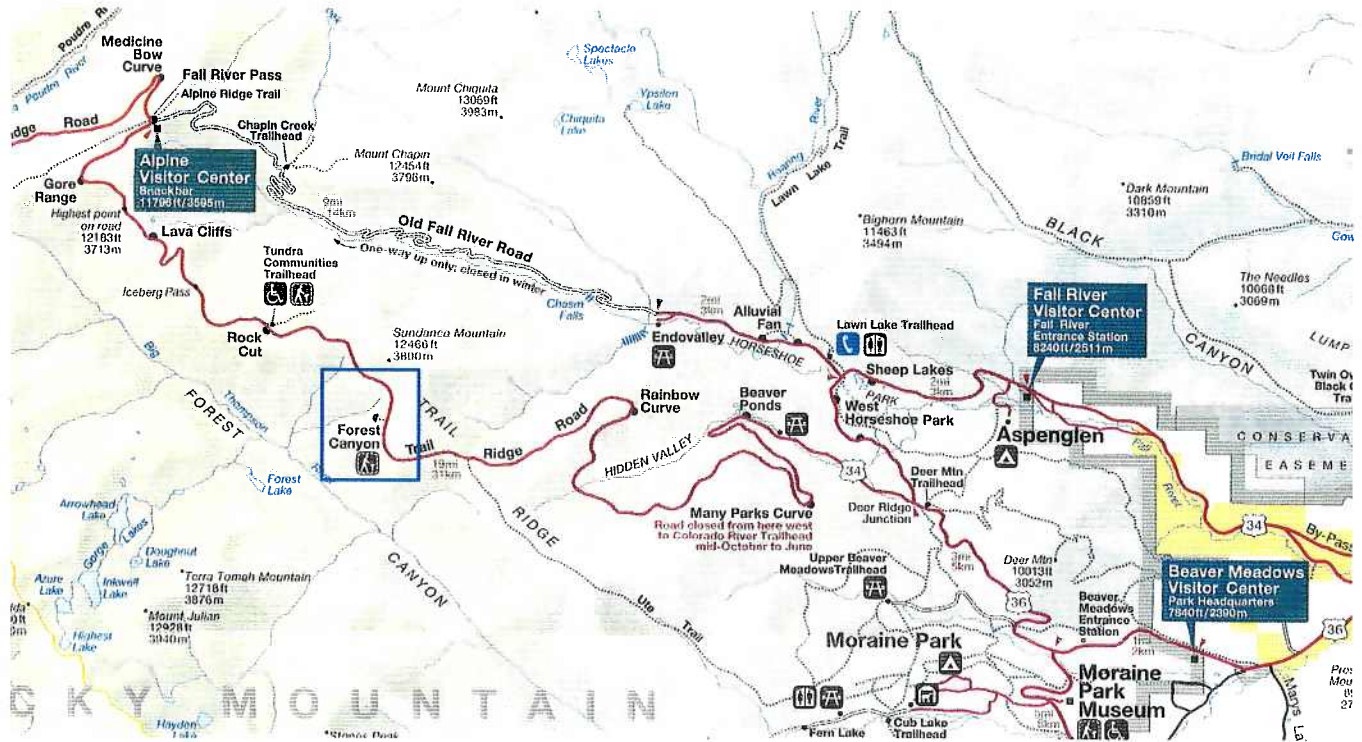


Figure 2-1

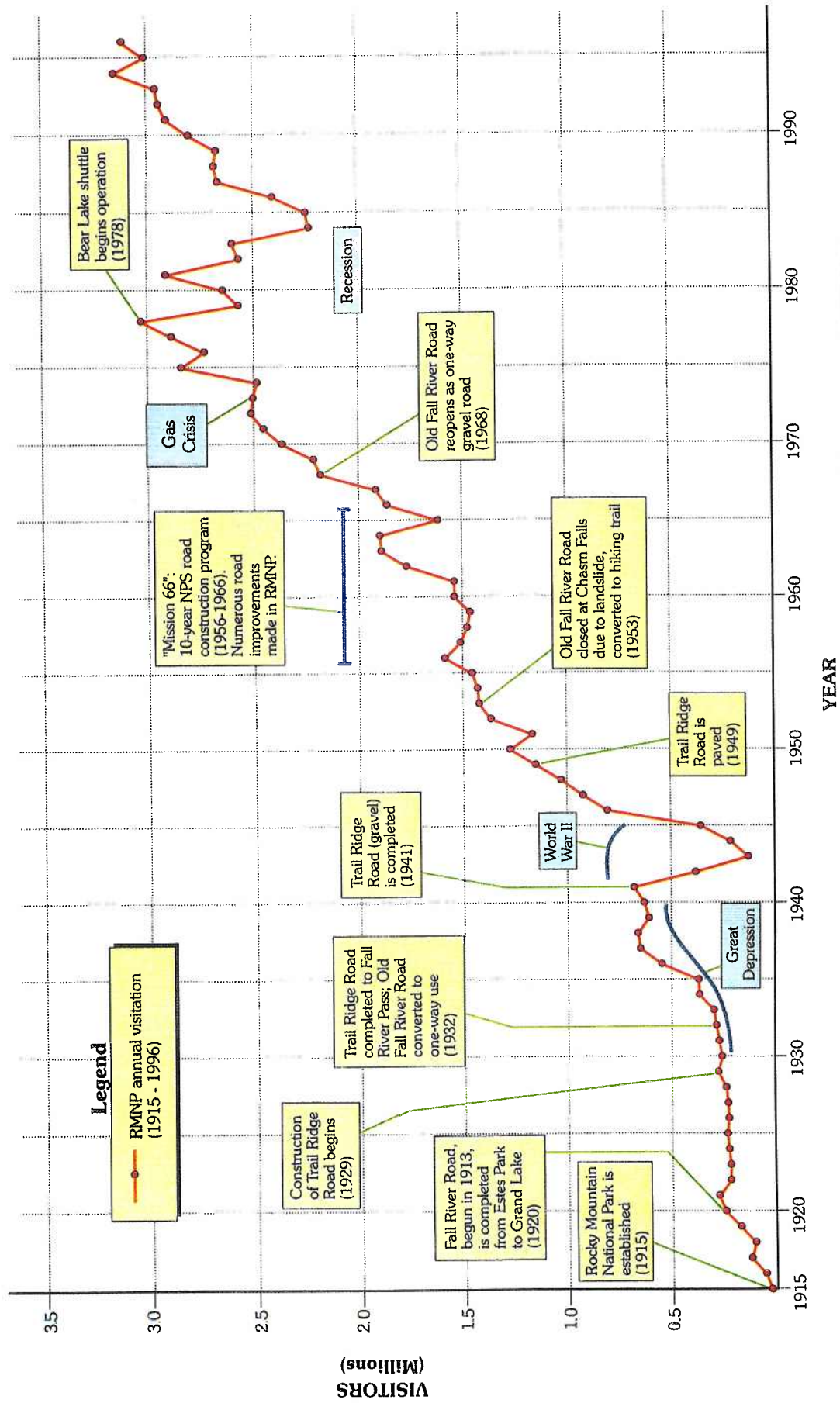


TRAIL RIDGE ROAD

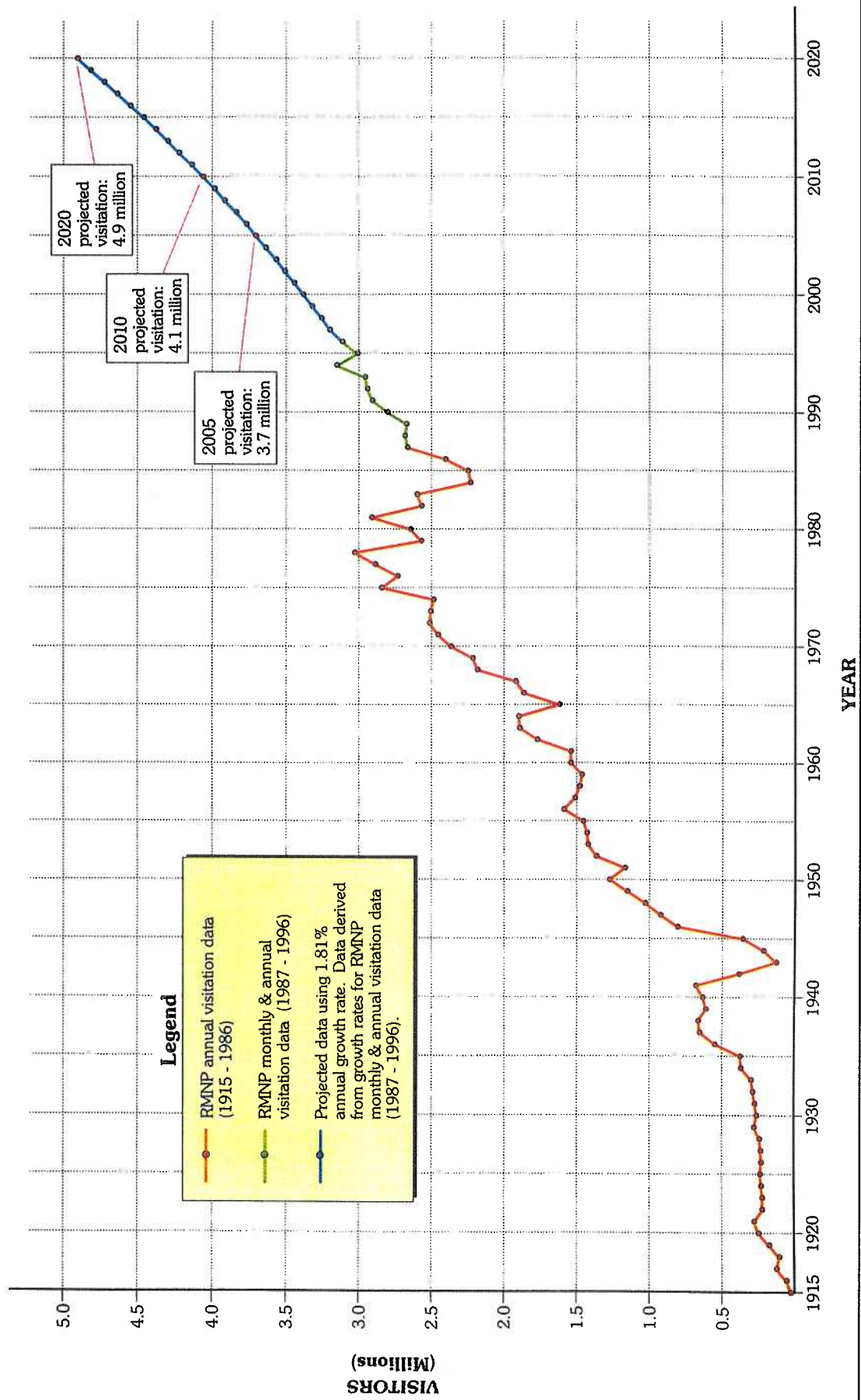


APPENDIX B

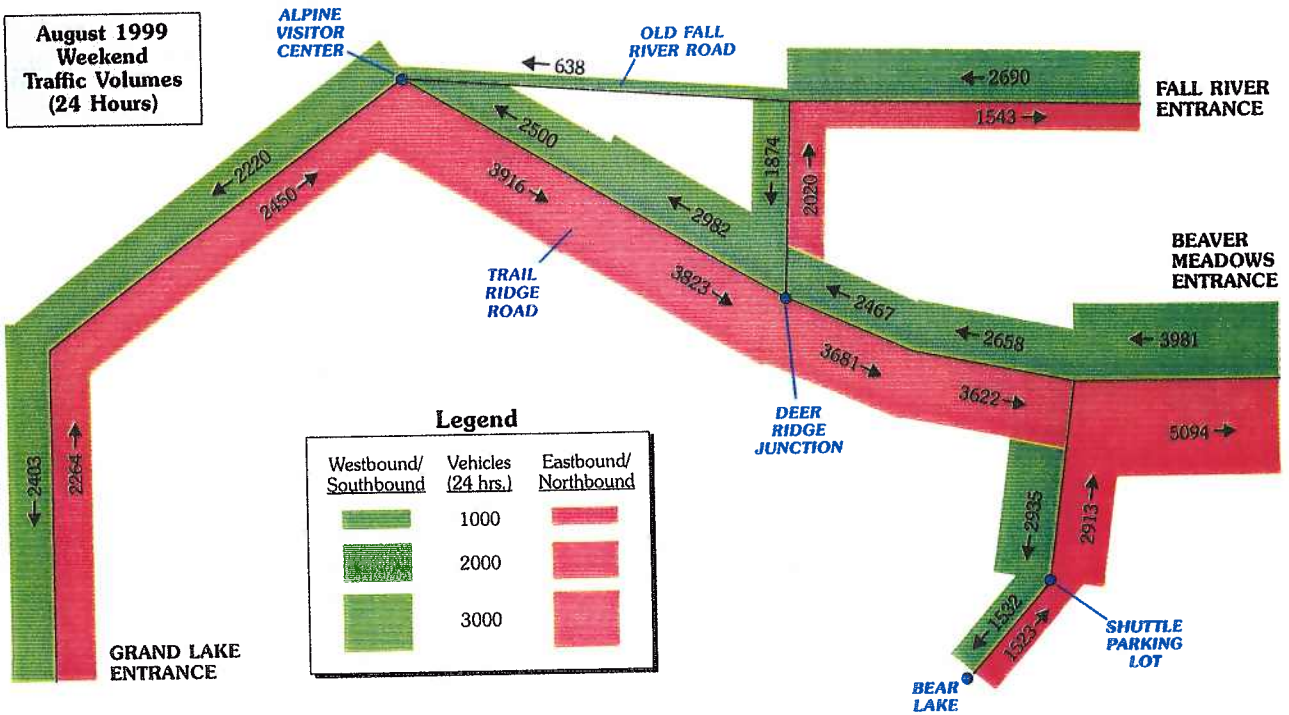
PARK VISITATION AND MAJOR MILESTONES, 1915 - 1996



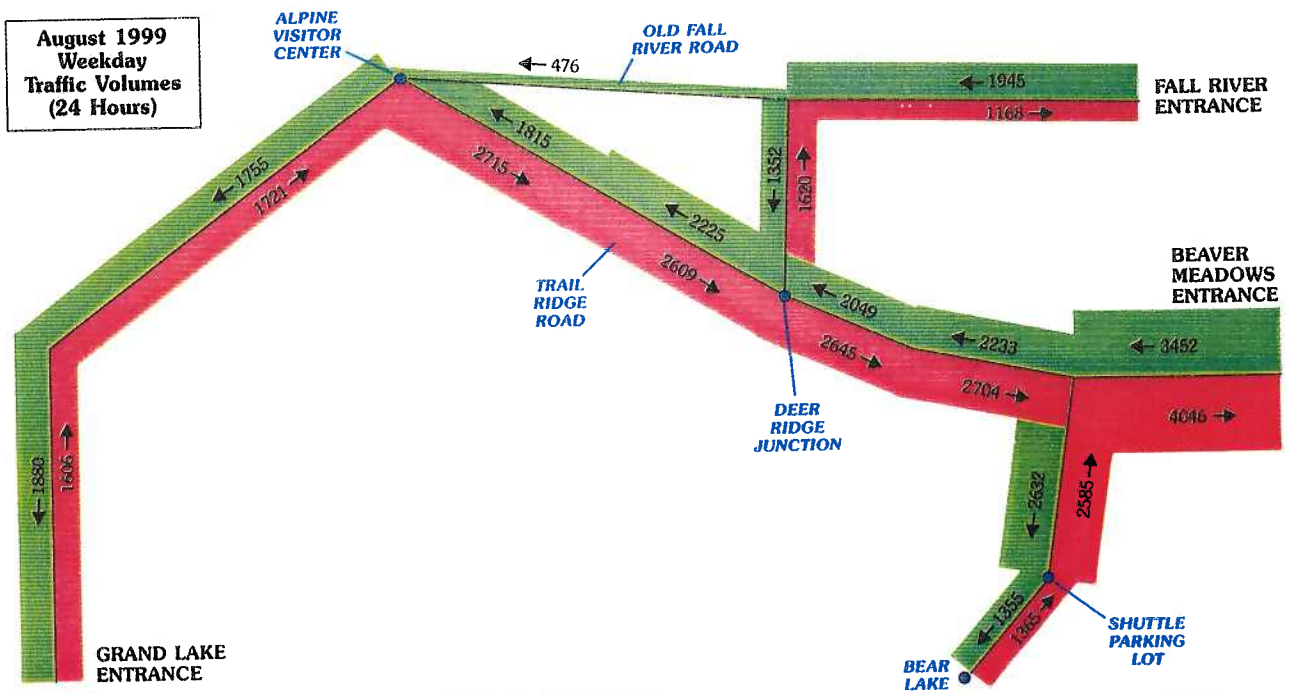
PARK VISITATION, 1915 - 2020



**August 1999
Weekend
Traffic Volumes
(24 Hours)**



**August 1999
Weekday
Traffic Volumes
(24 Hours)**



APPENDIX C

Boring Log

U.S. Department of Transportation
Federal Highway Administration
Central Federal Lands Highway Division



| | | | | |
|-------------------------------------------------------------------|-----------------------------|-----------------------------------------|-------------------------------|---------------|
| Project Name: Trail Ridge Road, CO PRP 10 (3) | | Boring No. 00P-101 | Date: July, 2000 | Sheet: 1 of 1 |
| Boring Location: 1.6 miles east of Alpine Visitor Ctr., 3.0 m Rt. | | Type of Boring: Continuous Flight Auger | | |
| Coordinates: | | Casing Used: HSA | Size: 100 mm | |
| Drill: CME 75 | Driller: Goodson and Assoc. | Boring Started: July 26,00 | Boring Completed: July 26, 00 | |
| Field Logged By : Charlie Martinez | | Elevation: Road Elevation | Weather: Cloudy | |
| Revisions By: Charlie Martinez | | Water Depth: | | |

| Depth Elevation, (m) | Run No. | Graphic Log | Length Rec. mm % Rec. | RQD | SPT Blows Per 150 mm | U.S.C.S | Description: (Density, Color, Type, Moisture, Other) |
|----------------------|---------|-------------|--------------------------|-----|----------------------|---------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------|
| -0.2 | AR #1 | | | | | | 0 - 0.20 m ASPHALT PAVEMENT 0.20 - 2.50 m Gray brown silty SAND and rock fragments Run #1: 0.2-1.5 m Gray brown silty SAND and rock fragments. |
| -1.5 | SPT #1 | | 200 73% | | 10/50-125 | SM | SPT #1: Recovered 200 mm of gray brown silty SAND with some gravel, slightly moist. |
| -2.5 | AR #2 | | | | | | Run #2: 1.75-2.5 m Gray brown silty SAND and rock Fragments to 2.5 m, then decomposed granite. 2.50- 3.80 m Brown gray predominantly DECOMPOSED GRANITE. |
| -3.5 | AR #3 | | | | | | SPT #2 attempt: but bouncing (10 blows for zero penetration). Run #3 Hard drilling decomposed granite. Auger refusal at 3.80 m |
| -3.8 | | | | | | | BHR at 3.8 m. |
| -6.0 | | | | | | | |

Boring Log

U.S. Department of Transportation
Federal Highway Administration
Central Federal Lands Highway Division



| | | | |
|--------------------------------------------------------------------|-----------------------------------------|-----------------------------|-------------------------------|
| Project Name: Trail Ridge Road, CO PRP 10 (3) | Boring No. 00P-102 | Date: July, 2000 | Sheet: 1 of 1 |
| Boring Location: 1.48 miles east of Alpine Visitor Ctr., 2.9 m Rt. | Type of Boring: Continuous Flight Auger | | |
| Coordinates: | Casing Used: HSA | Size: 100 mm | |
| Drill: CME 75 | Driller: Goodson and Assoc. | Boring Started: July 26, 00 | Boring Completed: July 26, 00 |
| Field Logged By: Charlie Martinez | Elevation: Road Elevation | Weather: Cloudy | |
| Revisions By: Charlie Martinez | Water Depth: | | |

| Depth Elevation, (m) | Run No. | Graphic Log | Length Rec. mm % Rec. | RQD | SPT Blows Per 150 mm | U.S.C.S | Description: (Density, Color, Type, Moisture, Other) |
|----------------------------|-----------|----------------|-----------------------------|-----|-------------------------------|---------|--------------------------------------------------------------------------------------------|
| -0.5 | -5 | | | | | | 0 - 0.5 m ASPHALT PAVEMENT and COLD MIX 0.5 - 2.5 m Brown silty SAND and rock fragments |
| -1.0 | AR #1 | | | | | | Run #1: 0.5-1.5 m Brown silty SAND and gravel- size rock fragments. |
| -1.5 | SPT #1 | | 275 61% | | 5/2/4 | SM | SPT #1: Recovered 200 mm of gray brown silty SAND and gravel, moist. |
| -2.0 | AR #2 | | | | | | Run #2: 1.95-2.5 m Brown silty SAND and rock fragments to 2.5 m, then brown red clay. |
| -2.5 | -2.5 | | | | | | 2.5- 4.8 m Brown red clayey SAND and gravel. |
| -3.0 | SPT #2 | | 400 89% | | 14/17/20 | SC | SPT #2: Recovered 400 mm of brown red clayey SAND, with some gravel, moist. |
| -3.5 | | | | | | | Run #3: 3.45-4.5 m Brown red clayey and gravelly SAND. |
| -4.0 | AR #3 | | | | | | |
| -4.5 | SPT #3 | | 275 100% | | 16/50 -125 | SC | SPT #3: Recovered 275 mm of brown red clayey SAND with some gravel, moist. |
| -5.0 | | | | | | | BHR at 4.8 m. |
| -5.5 | | | | | | | |
| -6.0 | | | | | | | |

Boring Log

U.S. Department of Transportation
Federal Highway Administration
Central Federal Lands Highway Division



| | | | |
|--------------------------------------------------------------------|-----------------------------------------|-----------------------------|-------------------------------|
| Project Name: Trail Ridge Road, CO PRP 10 (3) | Boring No. 00P-103 | Date: July, 2000 | Sheet: 1 of 1 |
| Boring Location: 1.45 miles east of Alpine Visitor Ctr., 3.0 m Rt. | Type of Boring: Continuous Flight Auger | | |
| Coordinates: | Casing Used: HSA | Size: 100 mm | |
| Drill: CME 75 | Driller: Goodson and Assoc. | Boring Started: July 26, 00 | Boring Completed: July 26, 00 |
| Field Logged By: Charlie Martinez | Elevation: Road Elevation | Weather: Cloudy | |
| Revisions By: Charlie Martinez | Water Depth: | | |

| Depth Elevation, (m) | Run No. | Graphic Log | Length Rec. mm % Rec. | RQD | SPT Blows Per 150 mm | U.S.C.S | Description: (Density, Color, Type, Moisture, Other) |
|----------------------------|---------|----------------|-----------------------------|-----|-------------------------------|---------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| -0.5 | -0.5 | | | | | | 0 - 0.5 m ASPHALT PAVEMENT and COLD MIX 0.5 - 4.25 m Brown silty SAND and gravel-size rock fragments Run #1: 0.5-1.5 m Brown silty SAND and gravel-size rock fragments. |
| -1.0 | AR #1 | | | | | | |
| -1.5 | SPT #1 | | 100 22% | | 5/7/6 | | SPT #1: Recovered 100 mm of GRAVEL, slightly moist. |
| -2.0 | AR #2 | | | | | | Run #2: 1.95-3.0 m Brown SAND and rock fragments, easy drilling. |
| -2.5 | SPT #2 | | 200 44% | | 9/10/7 | | SPT #2: Recovered 200 mm of brown silty SAND and gravel, slightly moist. |
| -3.0 | AR #3 | | | | | | Run #3: 3.45-4.25 m Brown silty SAND and rock fragments to 4.24 m, then auger refusal (predominantly decomposed granite). |
| -3.5 | | | | | | | |
| -4.0 | | | | | | | |
| -4.5 | | | | | | | BHR at 4.25 m. |
| -5.0 | | | | | | | |
| -5.5 | | | | | | | |
| -6.0 | | | | | | | |

Boring Log

U.S. Department of Transportation
Federal Highway Administration
Central Federal Lands Highway Division



| | | | |
|--------------------------------------------------------------------|-----------------------------------------|-----------------------------|-------------------------------|
| Project Name: Trail Ridge Road, CO PRP 10 (3) | Boring No. 00P-104 | Date: July, 2000 | Sheet: 1 of 1 |
| Boring Location: 1.48 miles east of Alpine Visitor Ctr., 2.5 m Lt. | Type of Boring: Continuous Flight Auger | | |
| Coordinates: | Casing Used: HSA | Size: 100 mm | |
| Drill: CME 75 | Driller: Goodson and Assoc. | Boring Started: July 26, 00 | Boring Completed: July 26, 00 |
| Field Logged By: Charlie Martinez | Elevation: Road Elevation | Weather: Cloudy | |
| Revisions By: Charlie Martinez | Water Depth: | | |

| Depth Elevation, (m) | Run No. | Graphic Log | Length Rec. mm % Rec. | RQD | SPT Blows Per 150 mm | U.S.C.S | Description: (Density, Color, Type, Moisture, Other) |
|----------------------------|------------|----------------|-----------------------------|-----|-------------------------------|---------|--------------------------------------------------------------------------------------------|
| -0.5 | -0.5 | | | | | | 0 - 0.5 m ASPHALT PAVEMENT and COLD MIX 0.5 - 4.8 m Brown silty SAND and rock fragments |
| -1.0 | AR #1 | | | | | | Run #1: 0.5-1.5 m Brown silty SAND and gravel-size rock fragments. |
| -1.5 | SPT #1 | | 250 56% | | 4/6/8 | GW-GM | SPT #1: Recovered 250 mm brown sandy GRAVEL, with some silt, moist. |
| -2.0 | AR #2 | | | | | | Run #2: 1.95-3.0 m Brown silty SAND and rock fragments. |
| -2.5 | SPT #2 | | 350 78% | | 10/13/50 | GW-GM | SPT #2: Recovered 350 mm of brown sandy GRAVEL, with some silt, slightly moist. |
| -3.0 | AR #3 | | | | | | Run #3: 3.45-4.5 m Brown SAND and rock fragments. |
| -3.5 | SPT #3 | | 275 100% | | 12/50 -125 | GW-GM | SPT #3: Recovered 275 mm of brown sandy GRAVEL, with some silt, slightly moist. |
| -4.0 | | | | | | | |
| -4.5 | | | | | | | |
| -5.0 | | | | | | | BHR (auger refusal) at 4.8 m. |
| -5.5 | | | | | | | |
| -6.0 | | | | | | | |

Boring Log

U.S. Department of Transportation
Federal Highway Administration
Central Federal Lands Highway Division



| | | | |
|--------------------------------------------------------------------|-----------------------------------------|-----------------------------|-------------------------------|
| Project Name: Trail Ridge Road, CO PRP 10 (3) | Boring No. 00P-105 | Date: July, 2000 | Sheet: 1 of 1 |
| Boring Location: 0.45 miles east of Alpine Visitor Ctr., 3.0 m Rt. | Type of Boring: Continuous Flight Auger | | |
| Coordinates: | Casing Used: HSA | Size: 100 mm | |
| Drill: CME 75 | Driller: Goodson and Assoc. | Boring Started: July 26, 00 | Boring Completed: July 26, 00 |
| Field Logged By: Charlie Martinez | Elevation: Road Elevation | Weather: Cloudy | |
| Revisions By: Charlie Martinez | Water Depth: | | |

| Depth Elevation, (m) | Run No. | Graphic Log | Length Rec. mm % Rec. | RQD | SPT Blows Per 150 mm | U.S.C.S | Description: (Density, Color, Type, Moisture, Other) |
|----------------------------|---------|----------------|-----------------------------|-----|-------------------------------|---------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| -0.125 | AR #1 | | | | | | 0 - 0.125 m ASPHALT PAVEMENT and COLD MIX 0.125 - 4.0 m yellow brown silty SAND and rock fragments Run #1: 0.125-1.5 m Brown silty SAND and gravel size rock fragments. |
| -1.5 | SPT #1 | | 275 61% | | 17/40/37 | SW-SM | SPT #1: Recovered 275 mm of gravelly SAND, trace of silt, slightly moist. |
| -2.5 | AR #2 | | | | | | Run #2: 1.95-3.0 m Brown silty SAND and rock fragments. |
| -3.0 | SPT #2 | | 100 100% | | 50-100 | SW-SM | SPT #2: Recovered 100 mm of gravelly SAND, with some silt, dry to slightly moist. |
| -4.0 | AR #3 | | | | | | Run #3: 3.45-4.0 m Brown silty SAND and rock fragments to 4.00 m, <u>then</u> predominantly decomposed granite. |
| -4.0 | | | | | | | BHR (auger refusal) at 4.0 m |
| -4.5 | | | | | | | |
| -5.0 | | | | | | | |
| -5.5 | | | | | | | |
| -6.0 | | | | | | | |

Boring Log

U.S. Department of Transportation
Federal Highway Administration
Central Federal Lands Highway Division



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|-------------------------------------------------------------------|-----------------------------------------|-----------------------------|-------------------------------|
| Project Name: Trail Ridge Road, CO PRP 10 (3) | Boring No. 00P-106 | Date: July, 2000 | Sheet: 1 of 1 |
| Boring Location: 0.4 miles east of Alpine Visitor Ctr., 4.0 m Rt. | Type of Boring: Continuous Flight Auger | | |
| Coordinates: | Casing Used: HSA | Size: 100 mm | |
| Drill: CME 75 | Driller: Goodson and Assoc. | Boring Started: July 26, 00 | Boring Completed: July 26, 00 |
| Field Logged By: Charlie Martinez | Elevation: Road Elevation | Weather: Cloudy | |
| Revisions By: Charlie Martinez | Water Depth: 4.5 m | | |

| Depth Elevation, (m) | Run No. | Graphic Log | Length Rec. mm % Rec. | RQD | SPT Blows Per 150 mm | U.S.C.S | Description: (Density, Color, Type, Moisture, Other) |
|----------------------------|---------|----------------|-----------------------------|-----|-------------------------------|---------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| -0.275 | AR #1 | | | | | | 0 - 0.275 m ASPHALT PAVEMENT and BASE COURSE 0.275 - 4.5 m Yellow brown silty SAND and rock fragments Run #1: 0.275-1.5 m Brown silty SAND and gravel size fragments. |
| -1.5 | SPT #1 | | 150 33% | | 6/3/4 | SM | SPT #1: Recovered 150 mm of silty SAND, trace of gravel, slightly moist. |
| -2.5 | AR #2 | | | | | | Run #2: 1.95-3.0 m Yellow brown silty SAND and rock fragments. |
| -3.0 | SPT #2 | | 400 89% | | 28/40/50 | SM | SPT #2: Recovered 400 mm silty SAND, with some gravel, dry to slightly moist. |
| -4.0 | AR #3 | | | | | | Run #3: 3.45-4.5 m Yellow brown silty SAND, and rock fragments to 4.50 m, <u>then</u> predominantly decomposed granite. Encountered water at 4.5 m. |
| -4.5 | SPT #3 | | | | | | SPT #3: attempt, bounced on rock (10 blows for no penetration) BHR at 4.50 m. |
| -5.0 | | | | | | | |
| -5.5 | | | | | | | |
| -6.0 | | | | | | | |

Boring Log

U.S. Department of Transportation
Federal Highway Administration
Central Federal Lands Highway Division



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|-------------------------------------------------------------------|--|-----------------------------|--|-----------------------------------------|-------------------------------|-----------------|
| Project Name: Trail Ridge Road, CO PRP 10 (3) | | | | Boring No. 00P-107 | Date: July, 2000 | Sheet: 1 of 1 |
| Boring Location: 0.3 miles east of Alpine Visitor Ctr., 3.8 m Rt. | | | | Type of Boring: Continuous Flight Auger | | |
| Coordinates: | | | | Casing Used: HSA | Size: 100 mm | |
| Drill: CME 75 | | Driller: Goodson and Assoc. | | Boring Started: July 26, 00 | Boring Completed: July 26, 00 | |
| Field Logged By: Charlie Martinez | | | | Elevation: Road Elevation | | Weather: Cloudy |
| Revisions By: Charlie Martinez | | | | Water Depth: | | |

| Depth Elevation, (m) | Run No. | Graphic Log | Length Rec. mm % Rec. | RQD | SPT Blows Per 150 mm | U.S.C.S | Description: (Density, Color, Type, Moisture, Other) |
|----------------------------|-----------|----------------|-----------------------------|-----|-------------------------------|---------|--------------------------------------------------------------------------------------------------------|
| -0.30 | AR #1 | | | | | | 0 - 0.30 m ASPHALT PAVEMENT and BASE COURSE 0.30 - 2.0 m yellow brown silty SAND and rock fragments |
| -0.5 | | | | | | | Run #1: 0.25-1.5 m Brown silty SAND and gravel-size fragments. |
| -1.0 | | | | | | | |
| -1.5 | SPT #1 | | 150 33% | | 2/6/13 | | SPT #1: Recovered 150 mm of silty SAND and gravel, slightly moist. |
| -2.0 | | | | | | | Run #2: 1.95-2.0 m Yellow brown silty SAND and rock fragments |
| -2.5 | | | | | | | BHR (auger refusal) at 2.0 m |
| -3.0 | | | | | | | |
| -3.5 | | | | | | | |
| -4.0 | | | | | | | |
| -4.5 | | | | | | | |
| -5.0 | | | | | | | |
| -5.5 | | | | | | | |
| -6.0 | | | | | | | |

Boring Log

U.S. Department of Transportation
Federal Highway Administration
Central Federal Lands Highway Division



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|--------------------------------------------------------------------|-----------------------------------------|-----------------------------|-------------------------------|
| Project Name: Trail Ridge Road, CO PRP 10 (3) | Boring No. 00P-108 | Date: July, 2000 | Sheet: 1 of 2 |
| Boring Location: 5.85 miles east of Alpine Visitor Ctr., 2.0 m Lt. | Type of Boring: Continuous Flight Auger | | |
| Coordinates: | Casing Used: HSA | Size: 100 mm | |
| Drill: CME 75 | Driller: Goodson and Assoc. | Boring Started: July 26, 00 | Boring Completed: July 26, 00 |
| Field Logged By: Charlie Martinez | Elevation: Road Elevation | Weather: Cloudy | |
| Revisions By: Charlie Martinez | Water Depth: | | |


| Depth Elevation, (m) | Run No. | Graphic Log | Length Rec. mm % Rec. | RQD | SPT Blows Per 150 mm | U.S.C.S | Description: (Density, Color, Type, Moisture, Other) |
|----------------------------|---------|----------------|-----------------------------|-----|-------------------------------|---------|------------------------------------------------------------------------------|
| -0.25 | | | | | | | 0 - 0.25 m ASPHALT PAVEMENT and BASE COURSE |
| -0.5 | AR #1 | | | | | | 0.25 - 6.45 m Yellow brown silty SAND and rock fragments |
| -1.0 | | | | | | | Run #1: 0.25-1.5 m Brown silty SAND and gravel-size fragments. |
| -1.5 | SPT #1 | | 250 58% | | 6/3/4 | SM | SPT #1: Recovered 250 mm of silty SAND, trace of gravel, slightly moist. |
| -2.0 | | | | | | | Run #2: 1.95-3.0 m Yellow brown silty SAND and rock fragments. |
| -2.5 | AR #2 | | | | | | |
| -3.0 | SPT #2 | | 350 78% | | 28/40/50 | SM | SPT #2: Recovered 350 mm silty SAND, trace of gravel, dry to slightly moist. |
| -3.5 | | | | | | | Run #3: 3.45-4.5 m Brown silty SAND, wet. |
| -4.0 | AR #3 | | | | | | |
| -4.5 | SPT #3 | | 450 100% | | 2/4/3 | SM | SPT #3: Recovered 450 mm brown silty SAND, wet. |
| -5.0 | | | | | | | Run #4: 4.95-6.0 m Brown silty SAND, wet. |
| -5.5 | AR #4 | | | | | | |
| -6.0 | | | | | | | |

Boring Log

U.S. Department of Transportation
Federal Highway Administration
Central Federal Lands Highway Division



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|--------------------------------------------------------------------|-----------------------------------------|-----------------------------|-------------------------------|
| Project Name: Trail Ridge Road, CO PRP 10 (3) | Boring No. 00P-108 | Date: July, 2000 | Sheet: 2 of 2 |
| Boring Location: 5.85 miles east of Alpine Visitor Ctr., 2.0 m Lt. | Type of Boring: Continuous Flight Auger | | |
| Coordinates: | Casing Used: HSA | Size: 100 mm | |
| Drill: CME 75 | Driller: Goodson and Assoc. | Boring Started: July 26, 00 | Boring Completed: July 26, 00 |
| Field Logged By : Charlie Martinez | Elevation: Road Elevation | Weather: Cloudy | |
| Revisions By: Charlie Martinez | Water Depth: | | |

| Depth Elevation, (m) | Run No. | Graphic Log | Length Rec. mm % Rec. | RQD | SPT Blows Per 150 mm | U.S.C.S | Description: (Density, Color, Type, Moisture, Other) |
|----------------------------|-----------|-----------------------------------------------------------------------------------|-----------------------------|-----|-------------------------------|---------|------------------------------------------------------|
| -6.5 | SPT #4 |  | 450 100% | | 6/9/12 | SM | SPT #4: Recovered 450 mm brown silty SAND, wet. |
| -7.0 | | | | | | | BHT=6.45 m |
| -7.5 | | | | | | | |
| -8.0 | | | | | | | |
| -8.5 | | | | | | | |
| -9.0 | | | | | | | |
| -9.5 | | | | | | | |
| -10.0 | | | | | | | |
| -10.5 | | | | | | | |
| -11.0 | | | | | | | |
| -11.5 | | | | | | | |
| -12.0 | | | | | | | |

Boring Log

U.S. Department of Transportation
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|--------------------------------------------------------------------|-----------------------------------------|-----------------------------|-------------------------------|
| Project Name: Trail Ridge Road, CO PRP 10 (3) | Boring No. 00P-109 | Date: July, 2000 | Sheet: 1 of 1 |
| Boring Location: 5.85 miles east of Alpine Visitor Ctr., 2.0 m Rt. | Type of Boring: Continuous Flight Auger | | |
| Coordinates: | Casing Used: HSA | Size: 100 mm | |
| Drill: CME 75 | Driller: Goodson and Assoc. | Boring Started: July 26, 00 | Boring Completed: July 26, 00 |
| Field Logged By: Charlie Martinez | Elevation: Roadway Elevation | Weather: Cloudy, moist | |
| Revisions By: Charlie Martinez | Water Depth: | | |

| Depth Elevation (m) | Run No. | Graphic Log | Length Rec. mm % Rec. | RQD | SPT Blows Per 150 mm | U.S.C.S | Description: (Density, Color, Type, Moisture, Other) |
|---------------------|---------|-------------|-----------------------|-----|----------------------|---------|------------------------------------------------------------------------|
| -0.25 | | | | | | | 0 - 0.25 m ASPHALT PAVEMENT and BASE COURSE |
| -0.5 | AR #1 | | | | | | 0.25 - 4.95 m Yellow brown silty SAND and rock fragments |
| -1.0 | | | | | | | Run #1: 0.25-1.5 m Brown silty SAND and gravel-size rock fragments. |
| -1.5 | SPT #1 | | 275 61% | | 6/8/7 | SM | SPT #1: Recovered 275 mm silty SAND, trace of gavel, slightly moist. |
| -2.0 | | | | | | | |
| -2.5 | AR #2 | | | | | | Run #2: 1.95-3.0 m Yellow brown silty SAND and rock fragments. |
| -3.0 | | | | | | | |
| -3.5 | SPT #2 | | 400 89% | | 9/7/7 | SM | SPT #2: Recovered 400 mm brown silty SAND, moist. |
| -4.0 | AR #3 | | | | | | Run #3: 3.45-4.5 m Brown silty SAND, rock fragments from 3.5 to 4.0 m. |
| -4.5 | | | | | | | |
| -5.0 | SPT #3 | | 450 100% | | 9/11/12 | SM | SPT #3: Recovered 450 mm brown silty SAND, moist. |
| -5.5 | | | | | | | |
| -6.0 | | | | | | | BHT=4.95 m |

APPENDIX D

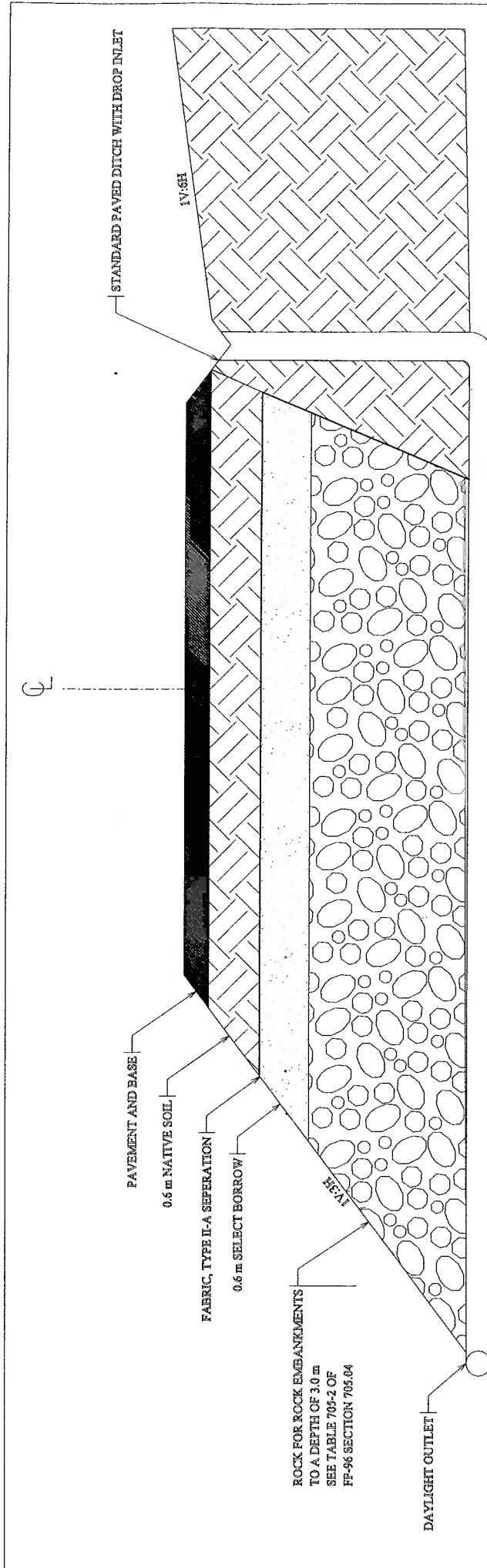


FIGURE 1: SUB-EXCAVATION SCHEMATIC FOR SITE A

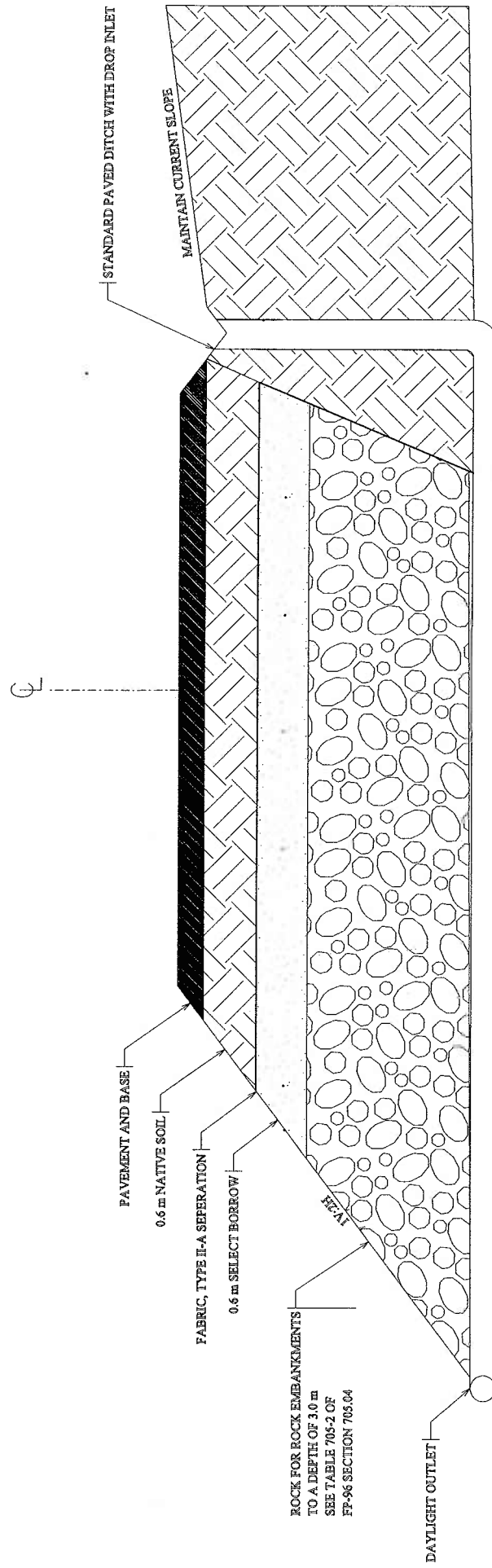


FIGURE 2: SUB-EXCAVATION SCHEMATIC FOR SITE B

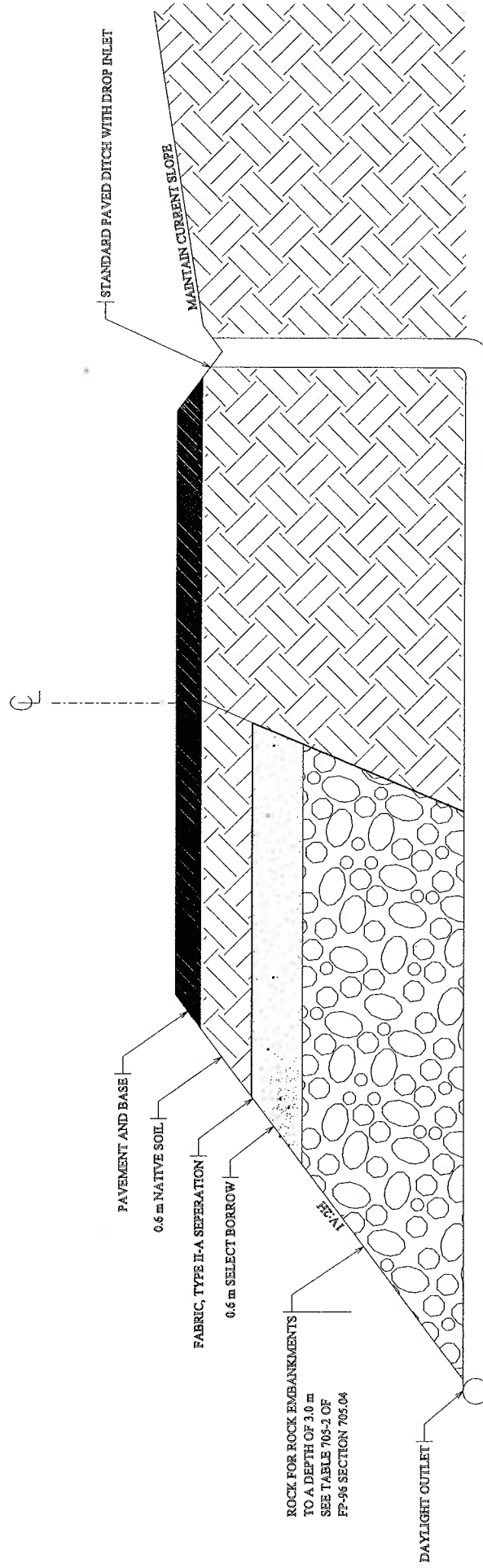


FIGURE 3: SUB-EXCAVATION SCHEMATIC FOR SITE B-1, SITE C, AND SITE D

APPENDIX E

TRAIL RIDGE ROAD



SITE A, BORING B-108 LOCATED 5.85 MILES EAST OF
ALPINE VISITOR CENTER, 2.0 m. LEFT



SITE A, BORING B-109 LOCATED 5.85 MILES EAST OF
ALPINE VISITOR CENTER, 2.0 m. RIGHT

TRAIL RIDGE ROAD



SITE A WITH NEIGHBORING TERRAIN, LOOKING SOUTH



AREA OF SUBSIDENCE ALONG ROAD AT SITE A, LOOKING NORTH

TRAIL RIDGE ROAD



EXTENTS OF SITE A, LOOKING NORTH



AREAS OF SUBSIDENCE ALONG ROAD AT SITE A, LOOKING SOUTH

TRAIL RIDGE ROAD



SCARP ALONG EAST SIDE OF SITE A



SCARP ALONG EAST SIDE OF SITE A

TRAIL RIDGE ROAD

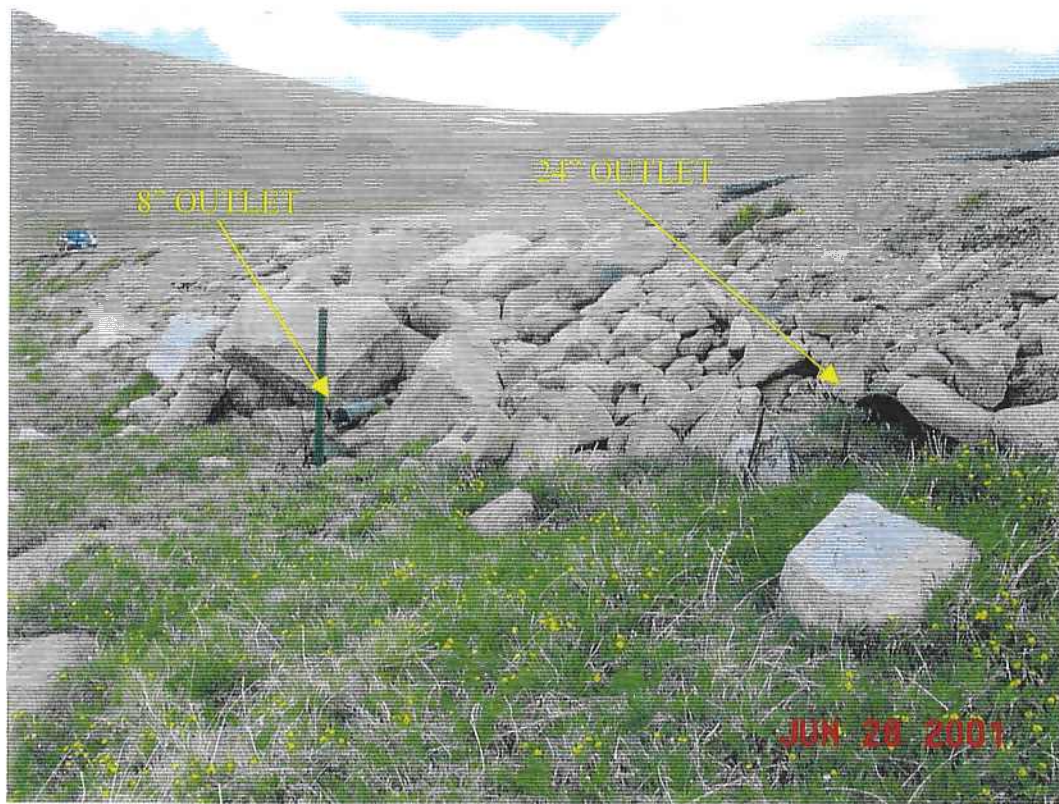


RIPRAP PROTECTION AND DRAIN PIPE AT SITE A



RIPRAP PROTECTION AND DRAIN PIPE AT SITE A

TRAIL RIDGE ROAD



RIPRAP PROTECTION AND DRAIN PIPE AT SITE A



RIPRAP PROTECTION AND DRAIN PIPE AT SITE A, LOOKING NORTH

TRAIL RIDGE ROAD



24" INLET AT SOUTH END OF SITE A



24" INLET AND DITCH AT SOUTH END OF SITE A

TRAIL RIDGE ROAD



STANDING WATER ALONG ROAD AT SITE A

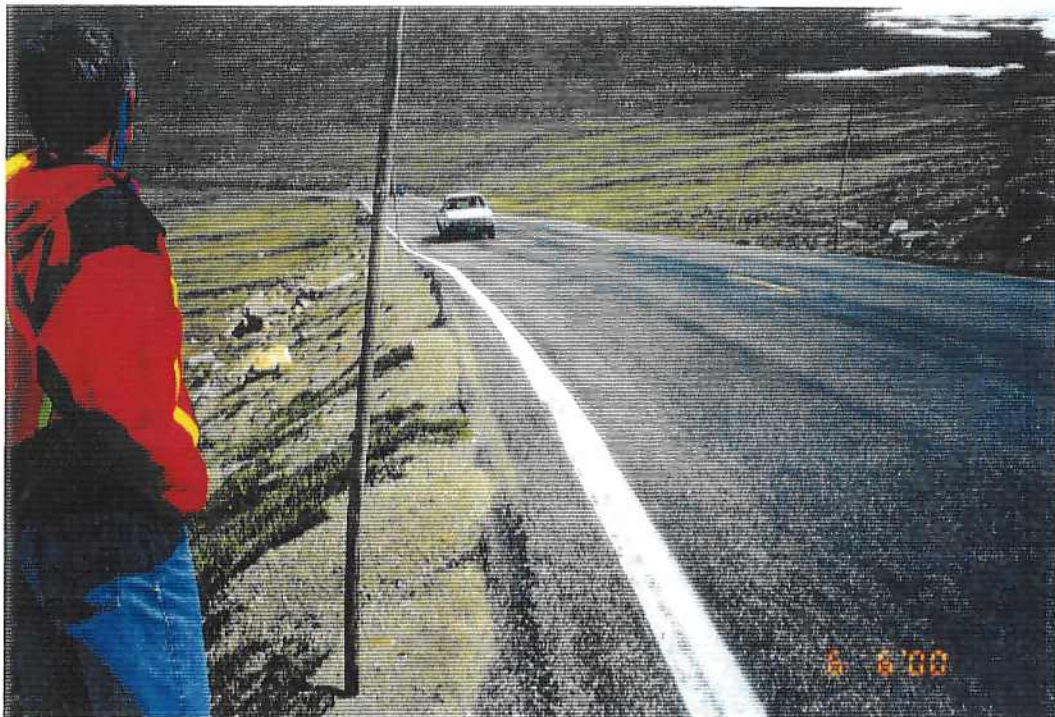


END OF PAVED DITCH ALONG ROAD AT SITE A

TRAIL RIDGE ROAD



AREAS OF SUBSIDENCE ALONG ROAD AT SITE A



AREAS OF SUBSIDENCE ALONG ROAD AT SITE A, LOOKING NORTH

TRAIL RIDGE ROAD



24" INLET AND DITCH AT SITE A, LOOKING SOUTH



TRANSVERSE CRACKING ALONG SITE A

TRAIL RIDGE ROAD



GRAVEL DITCH ALONG NORTH SIDE OF SITE A



18" DRAIN INLET AT MIDPOINT OF SITE A

TRAIL RIDGE ROAD



BORING B-101 AT SITE B, LOCATED 1.6 MILES EAST OF ALPINE VISITOR CENTER, 3.0 m RIGHT



BORING B-102 AT SITE B, LOCATED 1.48 MILES EAST OF ALPINE VISITOR CENTER, 2.9 m RIGHT

TRAIL RIDGE ROAD

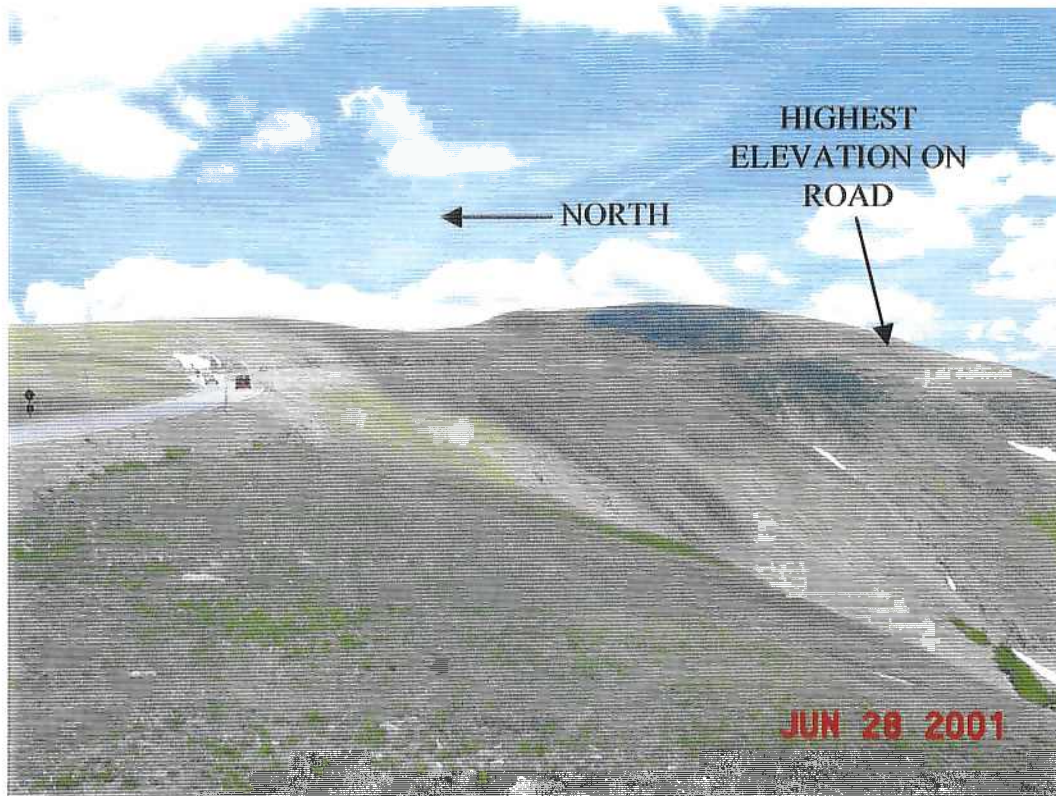


BORING B-103 AT SITE B, LOCATED 1.45 MILES EAST OF
ALPINE VISITOR CENTER, 3.0 m RIGHT



BORING B-104 AT SITE B, LOCATED 1.46 MILES EAST OF ALPINE
VISITOR CENTER, 2.5 m RIGHT

TRAIL RIDGE ROAD



SITE B FROM GORE RANGE LOOKOUT

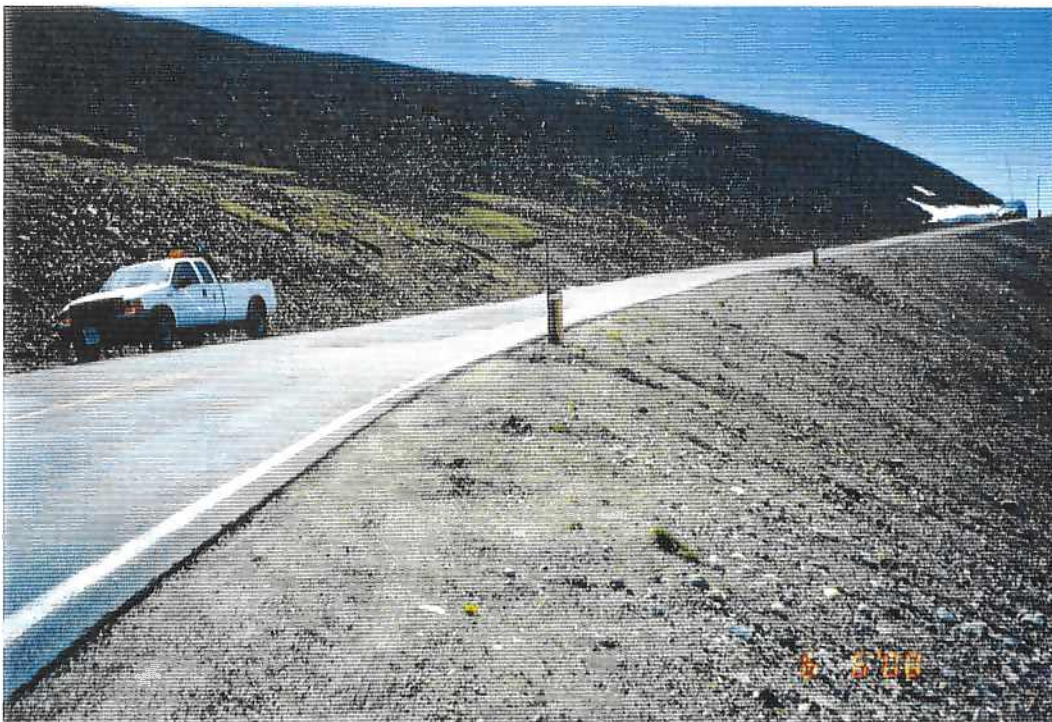


SITE B FROM GORE RANGE LOOKOUT

TRAIL RIDGE ROAD

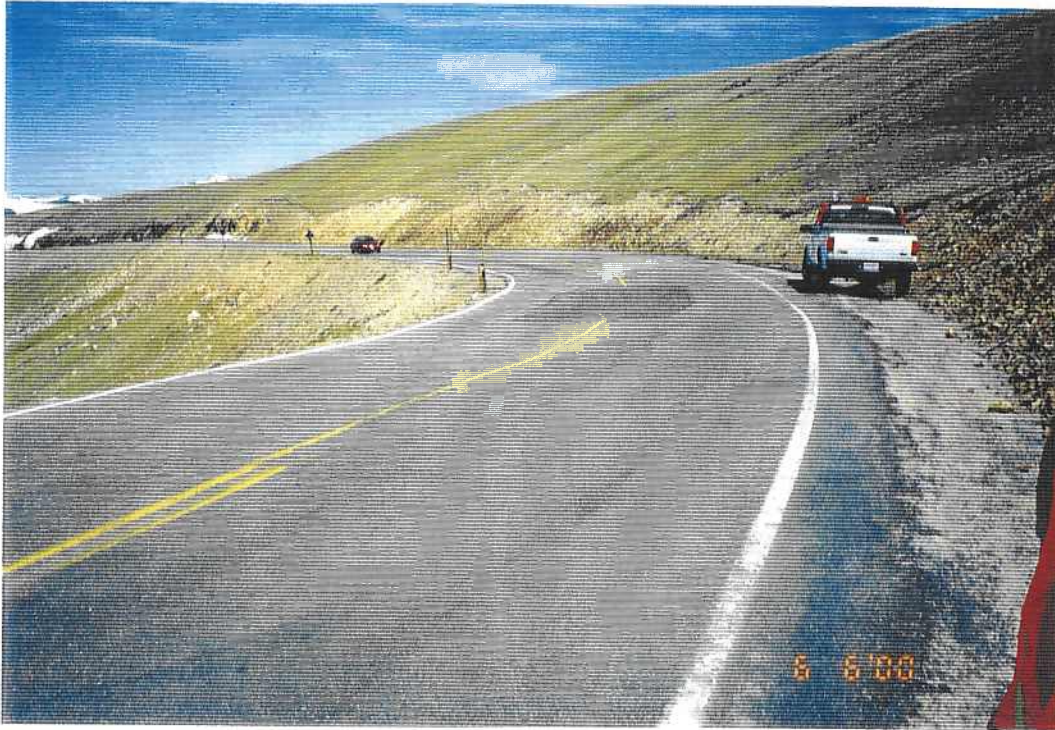


AREA OF SUBSIDENCE ALONG ROAD AT SITE B, LOOKING SOUTH



AREA OF SUBSIDENCE ALONG ROAD AT SITE B, LOOKING SOUTH

TRAIL RIDGE ROAD



AREA OF SUBSIDENCE ALONG ROAD AT SITE B, LOOKING NORTH



AREA OF SUBSIDENCE ALONG ROAD AT SITE B, LOOKING SOUTH

TRAIL RIDGE ROAD

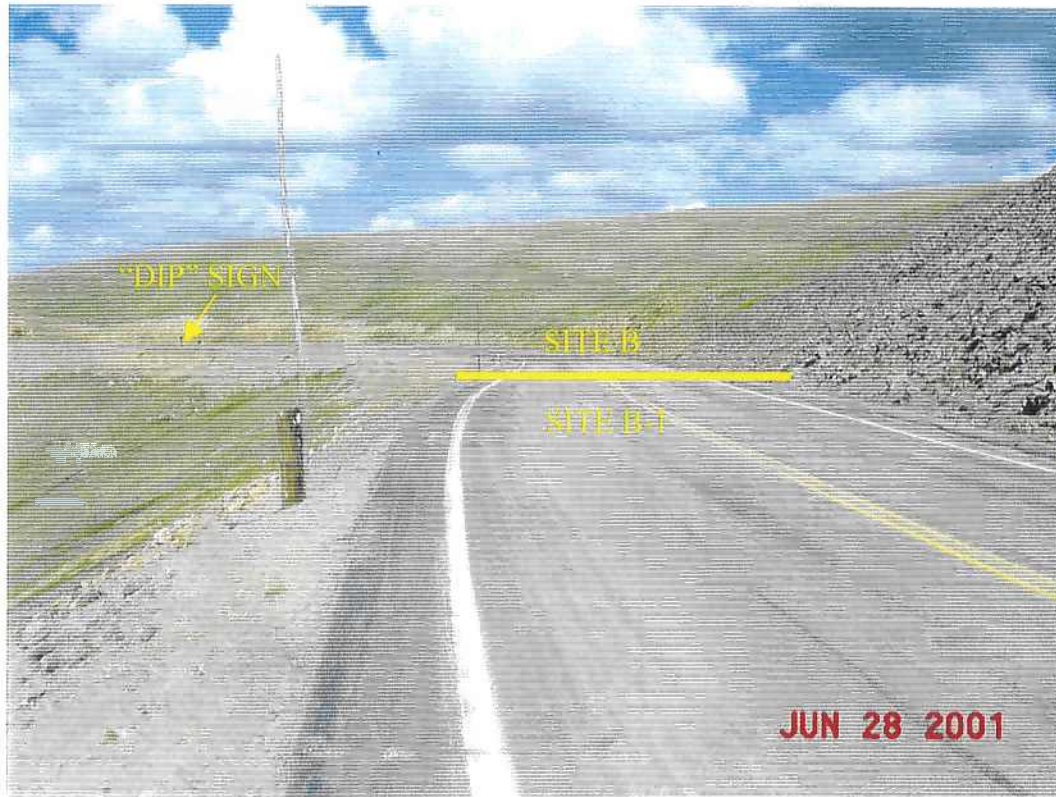


AREAS OF SUBSIDENCE ALONG ROAD AT SITE B



AREAS OF SUBSIDENCE ALONG ROAD AT SITE B

TRAIL RIDGE ROAD



AREAS OF SUBSIDENCE ALONG ROAD AT SITE B, LOOKING NORTH

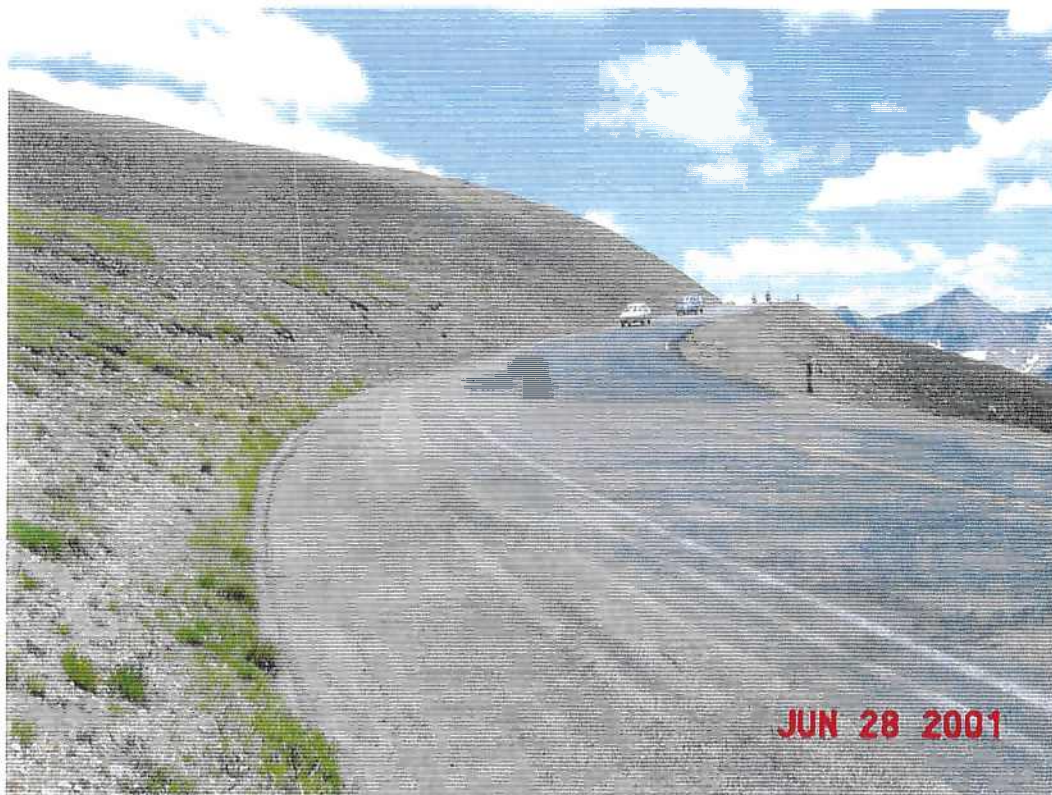


AREAS OF SUBSIDENCE ALONG ROAD AT SITE B, LOOKING NORTH

TRAIL RIDGE ROAD



FILL MATERIAL ON WEST SIDE OF SITE B, LOOKING NORTH



AREAS OF SUBSIDENCE ALONG ROAD AT SITE B, LOOKING SOUTH

TRAIL RIDGE ROAD



AREA OF SUBSIDENCE ALONG ROAD AT SITE B, LOOKING NORTH

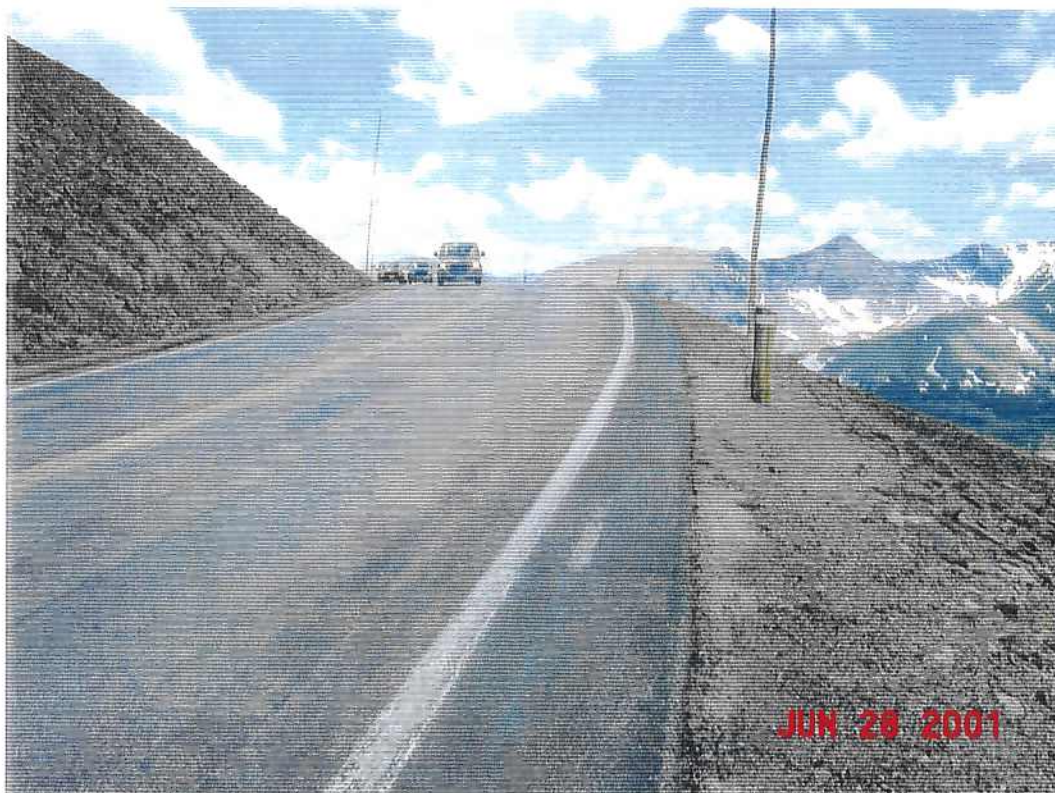


AREA OF SUBSIDENCE ALONG ROAD AT SITE B, LOOKING NORTH

TRAIL RIDGE ROAD



SITE B-1 AT HIGHEST ELEVATION ON ROAD, LOOKING SOUTH



SITE B-1 AT HIGHEST ELEVATION ON ROAD, LOOKING SOUTH

TRAIL RIDGE ROAD



SITE B-1 AT HIGHEST ELEVATION ON ROAD, LOOKING NORTH

TRAIL RIDGE ROAD



SITE C, LOOKING NORTHEAST



SITE C, LOOKING NORTHEAST

TRAIL RIDGE ROAD



ROLLED DITCH AT SITE C, LOOKING SOUTHWEST



ROLLED DITCH AT SITE C, LOOKING NORTHEAST

TRAIL RIDGE ROAD

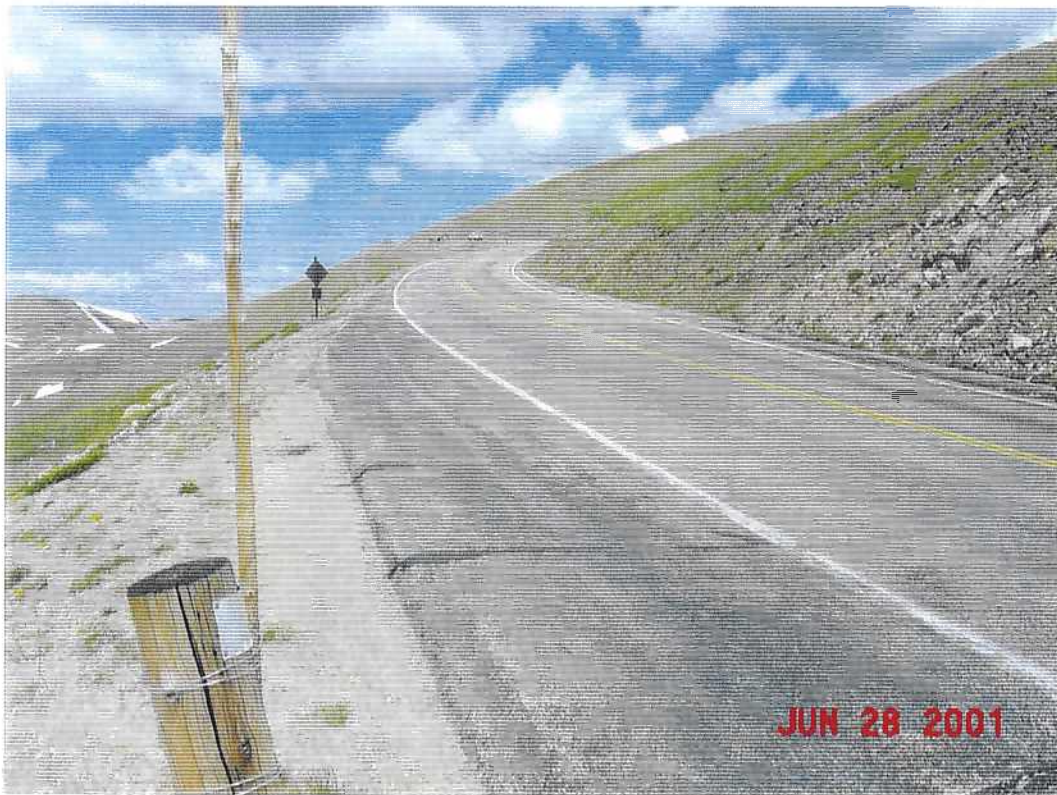


SITE C FROM ALPINE VISITORS CENTER

TRAIL RIDGE ROAD



SITE D, LOOKING SOUTHEAST



SITE D, LOOKING NORTHWEST

TRAIL RIDGE ROAD



SITE D, LOOKING NORTHWEST



SITE D, LOOKING NORTHWEST

TRAIL RIDGE ROAD



SHOULDER DROP ALONG ROAD AT SITE D